ANL/NSE-C2017-17156

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NEAMS Thermal-Fluids Test Stand for Fluoride-Slat Cooled, High Temperature Reactor Development

Final CRADA Report

Nuclear Science and Engineering Division

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Final CRADA Report

prepared by
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Non Proprietary

Final CRADA Report

For the Office of Scientific and Technical Information (OSTI)

CRADA Number: 2017-17156
CRADA Title: NEAMS Thermal-Fluids Test Stand for Fluoride-Slat Cooled, High Temperature Reactor Development
CRADA Start Date 10/11/2017 – **End Date** 10/10/2018

DOE Program or Other Government Support
Program office: DOE-NE
Program manager name: John Jackson
Program manager phone or email: john.jackson@inl.gov

Participant(s)

Participant 1 name: Kairos Power LLC
Complete address: 707 W. Tower Ave, Alameda, CA 94501

Participant 2 name: Click or tap here to enter text.
Complete address: Click or tap here to enter text.

Participant 3 name: Click or tap here to enter text.
Complete address: Click or tap here to enter text.

Argonne National Laboratory

Argonne PI(s): Click or tap here to enter text.

Funding Table

To add rows, right-click in bottom row and select “Insert” “rows above”.

	Planned Funding	Actual Funding	In-Kind
Government	$ 240,000	$ 240,000	
Enter Participant 1 here	$	$	$ 48,000
Enter Participant 2 here	$	$	$
Enter Participant 3 here	$	$	$
Total	**$** 240,000	**$** 240,000	**$** 48,000

Nature of Work

Describe the research (summary of Scope of Work and principal objectives of the CRADA):

Argonne National Laboratory entered into this Cooperative Research and Development Agreement (CRADA) to develop a functional NEAMS (Nuclear Energy Advanced Modeling and Simulation) thermal-fluid test stand (T/F-TS). The project initiated implementation and demonstration of the functionality of this T/F-TS to Kairos Power’s design optimization process for a key component of the Kairos Power FHR design – the heat exchanger. This effort has been run in parallel with Kairos Power’s rapid iterative design program on the experimental side.

The U.S. Department of Energy’s Nuclear Energy Advanced Modeling and Simulation (NEAMS) program is supporting the development of a novel system code (SAM) and a computational fluid dynamics tool (Nek5000); both will be used as part of this effort. Nek5000 provides capabilities for high resolution Direct Numerical Simulation (DES), Large Eddy Simulation (LES), Unsteady Reynolds Average Navier-Stokes (URANS) simulation, and reduced

order distributed resistance modeling. SAM is an advanced system code that leverages the MOOSE framework to deliver advances in software environment and design, numerical methods, and physical models. It features flexible multi-scale multi-physics integration with other high-fidelity tools, including Nek5000.

DOE mission area(s):
Energy and Environmental Science and Technology
Choose an item.
Choose an item.

Conclusions drawn from this CRADA; include any major accomplishments:
The work performed in this CRADA resulted in significant progress toward the development of a Thermal-fluid test-stand based on NEAMS tools. Significant work has been achieved in this area with simulations performed in Nek5000 of the heat and fluid flow in twisted tube heat exchangers and various software and modeling improvements in SAM geared toward heat exchanger simulations.
In particular a set of simulations of flow and heat transfer in twisted elliptical tube geometries has been performed with Nek5000. The method was validated by simulating a case at a moderate Reynolds number and relatively high Froude number. This case was demonstrated to predict a Nusselt number in excellent agreement with the applicable correlation found in literature. It was further shown that at lower Froude numbers, this agreement becomes much worse. Additional cases were then simulated with low Froude numbers for both a square and a triangular unit cell to test the effect of pitch-to-maximum diameter ratio for the purposes of future CFD modeling. The results have proven invaluable to understand the flow physics in twisted tubes and provide reference data for design. Results have been summarized in a conference article. Moreover, work in SAM has led to significant improvement of software quality, the creation of a set of benchmarks for natural circulation and other significant software improvement.

Technology Transfer-Intellectual Property
Argonne National Laboratory background IP:
SF-17-083 SAM (Systems Analysis Module)

Participant(s) background IP:
None

Identify any new Subject Inventions as a result of this CRADA:
None

Summary of technology transfer benefits to industry and, if applicable, path forward/anticipated next steps towards commercialization:
The work performed was instrumental in improving SAM and building confidence in its use for the simulation of Fllouride Salt Cooled High Temeperature Reactors (FHRs). Kairos is strongly considering SAM for the licensing application of its reactor techonology. This has significant benefit in terms of increased use of NEAMS tools as well as accelerated development of a promising reactor technology.
Moreover the Nek5000 simulations performed were instrumental in providing a basis for evaluating heat transfer performance of twisted-tube heat exchnagers at conditions relevant to FHRs.

Other information/results (papers, inventions, software, etc.):

Shaver, Dillon R., Lane B. Carasik, Elia Merzari, Nate Salpeter, and Edward Blandford. "Calculation of Friction Factors and Nusselt Numbers for Twisted Elliptical Tube Heat Exchangers Using Nek5000." In *ASME 2018 5th Joint US-European Fluids Engineering Division Summer Meeting*, pp. V002T09A030-V002T09A030. American Society of Mechanical Engineers, 2018.

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